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# Small Volume, Fuel Cell Inlet Fuel Gas Distributor Having Low Pressure Drop

## Technical Field

This invention relates to a fuel cell inlet fuel gas distributor having a plurality of fuel conduits of substantially equal length and flow capacity, which supply substantially uniform fuel substantially simultaneously across the length of a fuel inlet manifold.

## Background Art

The uneven distribution of fuel to the different fuel cells upon startup can lead to individual fuel cell fuel starvation, voltage reversal, and carbon corrosion, which ultimately results in severe performance loss.

In copending U.S. patent application 10/269,654, filed October 10, 2002, a fuel cell, fuel inlet flow control apparatus divides the fuel flow several times, successively, in a cascade fashion to provide a number of separate flows, and then spreads the flow so as to distribute the fuel substantially uniformly across the entrances to all of the fuel flow fields in the fuel cell stack. Fuel flow transients approach the fuel flow fields of all of the fuel cells in the stack substantially simultaneously and at substantially the same flow rate, during startup and other transient fuel flow conditions. In a disclosed embodiment, the flow is split successively four times and then the flow through all of the outlet passages from the cascade region impinges on a flat surface, which spreads the flow uniformly. Although the cascade fuel distributor does distribute the fuel quite evenly, it has a significant pressure loss, and the volume consumed

thereby is too large for certain applications. Geometrical constraints may prevent optimal design, in certain applications.

Disclosure of Invention

Objects of the invention include: simplified distribution of fuel at the fuel inlet of a PEM fuel cell; providing fuel of substantially uniform flow to the flow fields of all of the fuel cells in a fuel cell stack; substantially simultaneous delivery of a substantially equal amount of fuel to each of the flow fields in a fuel cell stack, increased durability of fuel cell stack, improved startup and other fuel input transients in fuel cell stacks; and improved, simplified fuel distribution in fuel cell stacks.

According to the present invention, an inlet fuel distributor for a fuel cell stack comprises a plurality of conduits of substantially the same length and substantially the same flow cross section that simultaneously and uniformly deliver fuel across the entire length of a fuel inlet manifold.

According to the invention, the inlet fuel of a fuel cell is evenly distributed to the fuel flow fields of all of the fuel cells in a fuel cell stack by providing, from a fuel supply pipe, a plurality of smaller pipes, each having the same total length and flow cross section, thereby providing flow through each distributor pipe which is the same as that in each other distributor pipe, with a simultaneous fuel front during startup.

In one form, an inlet fuel distributor of the invention comprises a plurality of channels formed in a relatively thin plate, the channels having substantially the same length, number of turns and flow cross section. According further to the invention, each channel

may or may not feed two exits into the inlet manifold to provide more uniform distribution.

According to an embodiment of the invention, small drain holes and channels may be provided where necessary to avoid water accumulation, in any given implementation of the invention.

According to the invention still further, the channels in an inlet fuel distributor for a fuel cell may have cross sections which are proportional to length, whereby the quantity and speed of the flow in all of the channels will be substantially equal, and the time of the arrival of the fuel front will be substantially the same at all points along the manifold.

Other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of exemplary embodiments thereof, as illustrated in the accompanying drawing.

Brief Description of the Drawings

Fig. 1 is a simplified, stylized, top perspective view of a first embodiment of the invention.

Fig. 2 is a perspective view of a fuel cell stack having an inlet fuel distributor according to the invention.

Fig. 3 is a perspective view of an inlet fuel distributor comprising channels formed in a plate in accordance with the invention;

Fig. 4 is a schematic illustration of an alternative form of inlet fuel distributor.

Fig. 5 is a perspective view illustrating an accumulated water outlet in an inlet fuel distributor of the invention.

Fig. 6 is a perspective view of the reverse side of the inlet fuel distributor shown in Fig. 5.

Fig. 7 is a schematic illustration of another alternative form of inlet fuel distributor.

Mode(s) for Carrying Out the Invention

A first embodiment of an inlet fuel distributor in accordance with the invention is illustrated in Fig. 1. A fuel supply pipe 13 feeds a chamber 14 out of which extend a plurality of fuel distribution tubes 17-23 of equal length and diameter, which terminate in corresponding holes 26 within a manifold cap 27. The manifold cap 27 is joined to a fuel inlet manifold 28. Because each of the tubes 17-23 is of the same diameter and the same length as each of the other tubes, the fuel will be distributed to all of the holes 26 in a substantially uniform manner. That is, when the fuel is first turned on, it will reach all of the holes 26 substantially simultaneously, and the flow through each of the tubes will be substantially identical to the flow in each other of the tubes. The holes 26 should be located such that there is one hole for every 10 to 20 cells. Alternatively, the distance between holes should be in the range of 40-80MM in a typical fuel cell stack with several hundred cells. Thus, a uniform flow with a substantially simultaneous fuel flow front is achieved by the embodiment of Fig. 1.

In certain instances, the amount of space, or volume, which is required in order to implement the embodiment of Fig. 1 may render it impractical. The ability to make the flow through the tubes 17-23 substantially simultaneous and identical becomes more difficult as the tubes become shorter, but is more easily achieved if the tubes are longer. Thus, the embodiment of Fig. 1 may present a

conflict between simultaneous and uniform flow versus the volume of space required to achieve it.

Referring to Fig. 2, a more compact inlet fuel distributor 31 receives fuel from the fuel supply pipe 13 and provides it to the fuel inlet manifold 28. The fuel inlet manifold 28 provides fuel to all of the fuel cells 33. In the two-pass configuration shown in Fig. 2, the fuel will flow from the fuel inlet manifold 28 to the right as seen in Fig. 2, across the top half of the fuel cells 33; then it will turn and flow downwardly and to the left in a fuel turnaround manifold 34, after which it will flow across the bottom half of the fuel cells 33 toward the left, as seen in Fig. 2, to the fuel exit manifold 35. Then it will pass through a fuel exhaust pipe 36, typically to a fuel recycle loop (not shown) which forms no part of the present invention.

Referring to Fig. 3, an inlet fuel distributor 31 according to the invention may comprise a plate 39 of metal, plastic, fiber reinforced plastic composite, or any other material compatible with fuel cell stack operating conditions. A plurality of channels 40-47 extend outwardly from a fuel inlet 50. Each of the channels 40-47, in the embodiment of Fig. 3, is split so as to provide two exits into a slot 55. Impingement of the fuel onto a bottom surface 56 of the slot tends to mix the fuel more uniformly and avoid "jetting" as a result of fuel being expelled from the exits 52, 53. Thus, there will be a more uniform front of fuel presented by the slot 55 to the fuel inlet manifold 28 (Fig. 2), which is forward of the inlet fuel distributor 31 as seen in Fig. 2.

In accordance with the invention, and as illustrated in Fig. 3, the channels 40, 41 are substantially identical; the channels 42, 43 are substantially identical; the channels 44, 45 are substantially identical, and the channels 46, 47 are substantially identical, except

for each being the mirror image of the other one of a pair. The length of each of the channels 40-47 is nearly identical to the length of each other one of the channels 40-47. The cross section flow area of each channel 40-47 is substantially identical to the cross sectional flow area of each other one of the channels 40-47. Thus, there is equivalent fluidic flow resistance in all the channels.

In the embodiment of Fig. 3, the lengthwise turning location of each turn, such as the turn 57 in the slot 47, is not the same as the lengthwise turning location of a corresponding turn, such as the turns 58-60 in the channels 41, 43 and 45. By inspection of Fig. 3, it can be determined that the lengthwise turning locations between turns, such as turns 57-58 and the next turn along the channel, are also different (except for the mirror image of each other channel). However, to the extent that this makes a difference in flow or timing, the length can be adjusted so that the time that it takes, to flow from the fuel inlet to the slot 55 through any one of the channels and its accompanying inlets, will be the same as the time it takes to flow from the fuel inlet 50 to the slot 55 through any other channel and inlets. This may also affect the amount of flow; the amount of flow also can be adjusted by adjusting the cross sectional flow area, at least at some portion of selected channels, thereby to balance both the quantity of flow and the timing for a fuel front introduced into the fuel inlet 50 to reach the slot 55 through any of the channels 40-47. A thin plate 61 covers the channels 40-47, above the slot 55.

An alternative form of inlet fuel distributor 31a is illustrated in Fig. 4, in which the channels 64 may have horizontal exits 65 (as viewed in Figs. 2 and 4), there being only one exit 65 per channel 64, and the exits 65 may cause fuel to impinge on a baffle 67, or

other surface, which may be part of the fuel inlet manifold 28 (Fig. 2).

Fig. 4 also illustrates that the channels need not be substantially orthogonal as in Fig. 3, but may take any desired shape. The choice of whether double or single exits 52, 53, 59 may be made to suit any desired implementation of the present invention. The use of more exits 52, 53 tends to mix the flow more thoroughly, but fewer exits 65 may simplify the analysis and adjustment of the design to provide both uniform quantity and uniform timing of the fuel front, upon startup.

Figs. 5 and 6 illustrate that a tendency for water accumulation, typically from recycle fuel which is provided to the fuel supply pipe 13 upstream of where shown in Fig. 2, may be accommodated by a small hole 62 at an appropriate point in one or more of the channels 40-47, such as the channel 41 illustrated in Fig. 5, with a minute drain channel 63 provided on the reverse side of the inlet fuel distributor 31. The channel 63 may simply exit into the fuel inlet manifold 28, at slot 55. The hole 62 must be sufficiently small that the amount of fuel which exits into the inlet manifold is insignificant.

Another embodiment of the invention, illustrated in Fig. 7, solves the water problem in a different fashion. Therein, all of the channels 67 are shaped so that there are no pockets or horizontal spots where water can accumulate. In other respects, the embodiment of Fig. 7 is the same as that of Fig. 3. As illustrated in Fig. 7, the channels 67 are not of equal length, but the shorter length is made up for by a sharper curvature therein and a longer length is made up for by a more gradual curvature therein. Tailoring as

described hereinbefore may be utilized in any case to assure substantially simultaneous, substantially equal flow of fuel.

The aforementioned patent application is incorporated herein by reference.

Thus, although the invention has been shown and described with respect to exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made therein and thereto, without departing from the spirit and scope of the invention.

We claim: